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Effects of Two Planting Patterns and Plant Densities on the Productivity and Profitability of Cotton

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Authors' contributions

This work was carried out in collaboration between all authors. Author DDF designed the study, wrote the protocol, and performed the statistical analysis. Author LLF provided economic imput. Authors RDP, RGL and CJF provided technical support and data analysis. Author WJG wrote the manuscript. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: To evaluate the effect of two planting patterns across two plant densities on cotton growth, yield, fiber quality, and net returns.
Study Design: Randomized complete block design with a 2 x 2 factorial treatment arrangement with 3 replicates was used for a total of 12 plots.
Place and Duration of Study: Studies were conducted during the 2003 and 2004 growing seasons on a producer's farm located south of Eagle Lake, Texas in Colorado County (29.49360 N, 96.34060 W).
Methodology: Rows were spaced 91.4-cm apart on raised beds. Plot size was eight rows by 972 m long. The two different factors included two row planting patterns, the solid pattern with every single row planted and the skip-row pattern with a 2x1 planting pattern where 2 rows are planted and 1 row is left fallow. For the skip-row pattern, rows three and six were not planted in the 8 row plot. The second factor was seeding rate with two plant populations of 84000 and 126000 plants/ha.

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Results: In neither year were any differences seen with seeding rate. In 2003, days to cut-out with the skip-row pattern were 92.4d while with the solid pattern days to cut-out were 87.9d and plant height with the skip-row pattern was 100 cm while with the solid pattern, plant height was 87 cm. Lint yield was 1504 kg/ha for the solid pattern while with the skip-row pattern lint yield was 1347 kg/ha. In 2004, lint yield with the solid pattern was 27% greater than the skip-row pattern. Slight differences between the two planting patterns were observed during 2004 in days to cut-out or plant height. In both years, the solid planting pattern produced a net dollar value/ha increase over the skip-row pattern and therefore should be the row pattern used along the upper Texas Gulf Coast.

Keywords: Cotton; skip-row; solid planting; plant growth; net returns.

1. INTRODUCTION

The practice of alternating two planted rows of cotton with two blank rows has been used for over 50 years in many areas of the U. S. where cotton is grown under low annual rainfall conditions to decrease production costs or when low prices favor skip-row planting patterns [1,2,3,4]. The use of skip-row planting increased in earlier years because allotment acreages could be calculated on planted rows only, rather than total land area and because skip-row plantings result in higher lint yields with this system of computation [5]. Dick and Owings [2] reported results of a 3 year study of skip-row cotton which showed increases in yield ranging from 24 to 127%. They compared skip-row patterns, 4x4 and 2x2 with solid planting and the greatest yield increase (127%) came in 1956 from the 2x2 pattern. Research from the Mississippi Delta region of the U. S. indicated that yield response from the 4x4 design would be expected to vary according to seasonal conditions, and that the greatest advantage from this pattern resulted from the more favorable growing seasons [3]. Yield increases in the 4 year study from this design ranged from 25 to 73% [3]. Grissom and Spurgeon [6] reported that cotton planted on Dubbs and Bosket soils in a 4x4 pattern produced 45% more yield and the 2x2 pattern produced 67% more than solid plantings. However, they reported no yield increase from skip-row planting on Sharkey clay where plants were approximately 61 cm tall.

Sturkie and Boseck [7] found that 3 year average yield increases for the 2x2 and 4x4 patterns over solid plantings were 57 and 31%, respectively where 272 kg/ha fertilizer was used and 46 and 28%, respectively where 408 kg/ha fertilizer was used. Langsford [8] tested 11 different systems of skip-row plantings, six of which involved interplanting with other crops. He showed that all skip-row systems increased cotton yield from 10 to 60%, indicating that cotton benefitted from the skip-row design, whether those rows were planted to other crops or left fallow. Other studies, depending on location, have shown skip-row lint yields for row spacings> 76-cm to be 54 to 100% of solid-planted yields on a land area basis [4,9,10,11,12].

With skip-row cotton, plants adjacent to the skipped rows partially compensate for lost yield by growing into the unplanted areas, such that the reduction in yield is less than proportional to the reduction in planted area [13]. This yield compensation may be due to less competition for nutrients and soil moisture, greater light penetration to lower leaves, or some combination of these factors [11].

Another strategy producers have utilized to decrease production costs is reducing the cotton seeding rate or plant densities [14]. Establishing an acceptable stand of cotton is paramount to obtaining high yields [14,15]. However, recent studies have shown no differences in cotton yield due to plant density [16,17,18,19,20]. The lack of yield differences can be explained by an increased number of main stem nodes, and location of sympodial and monopodial bolls on plants grown at lower densities [14,15,16].

Current technology allows cotton to be effectively seeded and harvested in alternative planting patterns. Also, reducing cotton plant densities can be a practical option for producers to decrease production costs. However, little information is available concerning the effect of alternative planting patterns utilizing different plant populations along the upper Texas Gulf Coast where moisture is usually not a limiting factor [21,22]. Therefore, the purpose of this study was to compare cotton response to conventionally planted pattern versus the skip-row 2x1 pattern along the upper Texas Gulf Coast. Additionally, partial budget analysis was performed to evaluate the returns of conventional planting patterns as compared to skip-row patterns.

2. MATERIALS AND METHODS

2.1 Field Studies

Studies were conducted during the 2003 and 2004 growing season on a producer’s farm located south of Eagle Lake, Texas in Colorado County (29.49360 N, 96.34060 W) to compare cotton response of skip-row pattern (2x1) with solid plantings and two different plant populations (84000 and 126000 plants/ha). Rows were spaced 91.4 cm apart on slightly raised (no more the 10 to 12 cm tall) beds. Plot size was 8 rows wide by 972 m long. For the skip-row treatments, the 2x1 configuration was obtained by not planting rows three and six in the eight row plot. Soil type at this site near Eagle Lake was a Weswood silt loam (fine-silty, mixed, superactive, thermic UdifluventicHaplustepts) with 1.0 % organic matter and pH 7.2. These studies were in different fields each year but in the same general area. Fertilizer (112, 34, and 60 kg/ha of N, P, and K, respectively) was applied by the grower as needed according to Texas A&MAgriLife Extension Service recommendations for cotton. Plots were maintained weed-free throughout the growing season using a preemergence application of flumeturon (Cotoran ®, Griffin, LLC, Valdosta, GA 31603) at 0.42 kg/ha plus S-metolachlor (Dual II Magnum®, Syngenta Crop Protection, Greensboro, NC 27419-0135) at the 0.43 kg/ha applied in a 30-cm band over the top after cotton was planted. In 2003, the plot area was cultivated three times while in 2004, glyphosate at 0.6 L/ha was applied once and plots were cultivated three times.

FiberMax 832B was planted on April 1, 2003 while DPL 444 BG/RR was planted on March 30, 2004 with an 8-row John Deere MaxEmerge II vacumeter planter. FiberMax 832B was not available the second year of the study; therefore, DPL 444 BG/RR was used since it is also medium-early and both have the same maturity. Beginning at first bloom, weekly counts of nodes above white flower values were obtained by sampling ten plants from each plot. Twenty plants per plot were measured at the end of the season to determine final plant height. Number of bolls to produce a kilogram of lint was obtained by hand-harvesting 0.002 of a hectare at three different places in each plot. Both sites were maintained under rain-fed conditions. Rainfall data was collected within 400 m of test sites and maintained by the producer.

2.2 Plot Harvest, Partial Budget, and Statistical Analyses

Seed cotton yields were obtained by machine harvesting with a two row cotton picker (John Deere 9910). The middle two rows of each plot were pickedand weight was determined with a portable cotton weigh wagon (West Texas Lee Co., model WT920-15). In both years, a grab sample of approximately 600 grams of seed cotton from each of the plots was ginned on a 10-saw Eagle Laboratory Gin to determine lint yield and turnout. A 30 gram lint sample from each of the plots was then sent to the International Textile Center (Lubbock, TX) for fiber quality analysis testing for micronaire, staple length, uniformity, strength, and elongation using aUster HVI 1000 analyzer.

Cotton yield was determined by calculating yield based on total land area not planted area. The economic analysis included in this study is based on partial budgeting of net returns above seed and seed technology costs, in-furrow insecticide costs, banded herbicide costs, picking costs and ginning costs. This partial budgeting technique is appropriate since all other factors of production were the same for both systems. Prices from 2012 were used in the partial budgets with the following assumptions for each year [23]. In 2003, FiberMax 832B had only Bollgard® technology [24,25,26] but no glyphosate tolerance and the technology fee was $92.50/bag. In 2004, DPL 444 BG/RR had Bollgard® and Roundup-Ready® [27,28,29] technology with a technology fee of $262.70/bag. In both years all other assumptions were the same. The loan value for solid and skip-row planting was$1.194/ kglintwhile seed cotton was $292.11/ metric ton. Seed cost was $150/bag (without technology fee) based on 250,000 seed/bag while the cost of thiamethoxam seed treatment was $41.90/bag. S-metolachlor costs were $2.56/ha while flumeturon costs were $1.61/ha. Picking charges was $0.267/kg for lint and ginning charge was calculated at $0.0606/kg of seed cotton.

The treatment design was a factorial arrangement using a randomized complete block design with planting pattern and plant population as factors. An analysis of variance was performed using the ANOVA procedure for SAS (SAS Institute. 1998. SAS user's guide. SAS Inst.,Cary, NC.) to evaluate the significance of planting pattern and plant population on cotton growth, yield, and fiber quality. Treatments means were separated by Fisher's protected least significant difference test at $P = 0.05$.

3. RESULTS AND DISCUSSION

Since environmental conditions were different in each year of the study, it was thought to analysize each year separately to determine if environmental conditions, specifically rainfall, were a factor in the results.

3.1 Rainfall

Rainfall amounts along the upper Texas Gulf Coast were variable for the two years (Table 1). Rainfall during the 2003 growing season was 41% below normal for most of the growing season with July being the only month that had above average rainfall. In 2004, below average rainfall was received for March and July; however, rainfall amounts for April, May, and June were 1.4, 1.7, and 2.5 times the total average rainfall for those three months respectively (Table 1). Below average rainfall was received for March and July. Overall, rainfall during the 2004 growing season was 40% above normal (Table 1) [30].

Table 1. Monthly rainfall (mm) during the growing season at the study locations during 2003 and 2004

Month	2003	2004	20-yr average
March	33.3	65.0	80.8
April	8.6	117.4	83.8
May	4.1	205.7	119.4
June	96.5	321.6	126.5
July	175.3	7.9	83.1
August	23.9	98.8	88.9
Total	341.7	816.4	582.5

3.2 Seeding Rate

Plant density had no effect on any variable evaluated (Table 2). Therefore, only differences in planting pattern are discussed. Lack of an effect of seeding rate may be the result of plant compensation, producing increased yield per plant with fewer plants, while in the higher planting density, individual plant productivity decreased (authors' personal opinion).

Other researchers have also noted the lack of plant density effect on several variables. Seibert and Stewart [20] observed that plant density did not influence plant height; however, Seibert et al. [19] found a positive relationship between plant height and plant density. Pettigrew and Johnson [31] reported no differences between cotton plant densities of 7, 9, 11, or 13 plants m^2 for plant height and total nodes/plant. Stephenson et al. [14] found that the percentage of total bolls associated with the first position increased with increasing plant densities. In other research, O'Berry et al. [32] found no differences in the number of first and second position bolls per plant as plant densities increased. The effect of plant densities on seed cotton yield has also been variable. Stephenson and Brecke [33] found that cotton seeded at 7 plants m^2 in 19 cm twin rows yielded 220 kg/ha more than 7 plants m^2 in 76 cm single row cotton, but differences between planting patterns were not observed at plant densities of 13 and 26 plants m^2. Others have found that lint yield was not influenced by plant density when cotton was seeded in 90 or 97 cm rows [16,17,19,20]. Plant density also had no effect on fiber quality [14,31,32]. Stephenson et al. [14] reported that plant density had no effect on fiber length, micronaire, strength, or uniformity while O'Berry et al. [32] observed no effect of plant density on lint percentage. Other work indicated that plant density did not influence fiber strength or uniformity, but micronaire was slightly affected [31]. In contrast, Darawsheh et al. [34] observed decreased fiber micronaire and length when plant densities were increased, but fiber strength and uniformity were not affected.

Table 2. Plant density effects on study parameters (P > F)*

Variables	2003	2004
Days to cutout (number)	0.2644	0.8830
Plant height (cm)	0.8028	0.3765
Open bolls (number)	0.1321	-
Bolls/kg lint (number)	0.2560	-
Lint yield (kg/ha)	0.5413	0.9493
Micronaire (units)	0.2231	0.6452
Staple length (mm)	0.1055	0.0683
Uniformity (%)	0.1561	0.9786
Strength (gr/tex)	0.4219	0.4569
Elongation (units)	0.1116	0.5239

**P =0.05*

3.3 Agronomic Response to Planting Pattern

3.3.1 Days to cut-out

In 2003, the solid pattern resulted in a 5% reduction in the number of days to cut-out over the skip-row pattern (Table 3) while in 2004 no differences were noted between the two planting patterns (Table 4). Since early crop maturation and harvest of cotton can enhance production efficiency by alleviating late-season risks associated with adverse weather and insect problems [35], the reduction seen in 2003 is important in getting the crop out of the field.

Table 3. Cotton response to skip-row versus solid plantings in 2003*

Planting pattern	Plant population (Number/ha)	Days to cutout (Number)	Plant ht (cm)	Number open bolls (1000's/ha)	Bolls/kg (Number)	Lint yield (Kg/ha)
Skip-row	84000	92.7	100.3	620.4	493.4	1357
	126000	92.0	99.3	627.0	481.8	1336
		92.4a	99.8a	623.7a	487.6a	1347b
Solid	84000	88.7	87.1	699.6	472.3	1476
	126000	87.0	87.1	741.4	505.3	1531
		87.9b	87.1b	720.5a	488.8a	1504a

**Means in a column followed by the same letter are not significantly different at P= .05*

3.3.2 Plant height

In 2003 the skip-row pattern produced a taller plant than the solid pattern (Table 3) while in 2004 not much differences in plant height were noted (Table 4). This difference in plant height in 2003 may be due to the below average rainfall during the early part of the growing season and thus the cotton plant better utilized moisture in the skip-row pattern while in 2004, rainfall from April to June was above normal and the plants had sufficient moisture in both planting patterns (authors' personal observation). Buehring et al. [9] reported that row pattern did not have any effect on plant height. Seibert and Stewart [20] observed that plant density did not influence plant height; however, Seibert et al. [19] found a positive relationship between plant height and plant density. Pettigrew and Johnson [31] reported no differences between cotton plant densities of 7, 9, 11 or 13 plants m^2 for plant height and total nodes per plant.

Table 4. Cotton response to skip-row versus solid plantings in 2004

Planting pattern	Plant population (Number/ha)	Days to cutout (Number)	Plant height (Cm)	Lint yield (Kg/ha)
Skip-row	84000	107.3	100.8	1057
	126000	105.3	99.1	1036
		106.3a	100.0a	1047b
Solid	84000	104.0	94.7	1299
	126000	105.7	96.5	1328
		104.9a	95.6a	1314a

**Means in a column followed by the same letter are not significantly different at P= .05*

3.3.3 Open bolls and bolls/kg lint

In 2003, solid planting produced numerically more bolls than skip-row but no statistical differences were seen with respect to bolls/kg lint with either planting pattern (Table 3). Hawkins and Peacock [1] reported that the solid planting produced smaller bolls than the skip row planting and they concluded that an increase in boll size, along with more bolls per lateral branch and more lateral branches per plant [34], contributed to increased yields from skip-row planting.

3.3.4 Lint yield

In 2003, the solid planting outyielded the skip-row planting by 157 kg (Table 3) while in 2004 the solid planting yielded 267 kg more cotton than the skip-row planting (Table 4). Mixed results have been seen with skip-row vs solid plantings [1,2,4,5,10,11,12,14,36]. Hawkins and Peacock [1] reported that skip-row plantings increased cotton yield over solid plantings by 20 to 75%.Kittock [5] reported that the skip-row plantings (1x1, 2x1, 2x2, 4x2, and 6x2) gave significant increases in lint yield of Pima cotton when computed on a planted area basis with the most benefit from skip-row obtained in the outside rows. He also stated when computed on the total land area basis, all skip-row patterns gave reduced yields. Bruce [37] found 27 and 34% yield increases from 2x1 planting, compared with solid planting, and attributed some of the differences to more available soil water for plants in skip-row. Parvinet al. [4] stated that a hectare of solid cotton exhibited higher yields than a hectare of skip-row cotton. They also reported the narrower the skip, the closer the yield of the skip-row cotton approached the yield of solid planted cotton.

3.4 Fiber Quality

3.4.1 Micronaire

No significant difference in micronaire values was seen in either year (Table 5). This is in contrast to Larson et al. [13] who reported under nonirrigated conditions that miconaire values were lower for skip-rows than for solid plantings. McAlister [38] and Vories et al. [39] reported lower micronaire in narrow-row spacings than in wide-row spacings. However, Doederlein et al. [40] found no differences in micronaire between solid and skip-row for 102-

cm row spacings in Texas while Hons and McMichael [11] reported higher micronaire for solid rows than skip-row at 100-cm row spacing.

Table 5. Cotton fiber characteristics from skip-row versus solid plantings*

Planting pattern	Plant population	Micronaire (Units)		Staple length (mm)		Uniformity (%)		Strength (Gr/tex)		Elongation (Units)	
		2003	**2004**	**2003**	**2004**	**2003**	**2004**	**2003**	**2004**	**2003**	**2004**
Skip-row	84000	3.8	4.2	31.5	29.2	85.1	84.3	32.2	31.4	3.8	6.4
	126000	3.8	4.2	31.2	29.7	84.0	84.4	34.1	32.7	3.5	6.3
		3.8a	4.2a	31.4a	29.5a	84.6a	84.4a	33.2a	32.0a	3.7a	6.4b
Solid	84000	3.6	4.2	31.0	29.2	84.4	84.7	31.9	31.6	3.8	6.6
	126000	3.9	4.1	30.5	29.5	83.8	84.6	31.6	31.8	3.6	6.5
		3.8a	4.2a	30.7b	29.4a	84.1a	84.7a	31.8a	31.7a	3.7a	6.6a

**Means followed by the same letter for each parameter are not significantly different at P = 0.05.*

3.4.2 Staple length

In 2003, the skip-row pattern had slightly longer staple length than the solid planting while in 2004 no differences were noted (Table 5). Larson et al. [13] reported under irrigation that the skip-row pattern had longer staple length than did solid rows. They speculated that decreased staple length may be due to differences in harvest method. Bange et al. [41] in Australia, reported increased staple length for skip-rows relative to solid rows at 100-cm spacings.

3.4.3 Uniformity and fiber strength

No differences in uniformity or fiber strength with any planting pattern were observed in either year (Table 5). Larson et al. [13] and Stephenson et al. [14] also reported no differences in these lint quality factors with any planting pattern.

3.4.4 Elongation

In 2003, no differences in fiber elongation were noted with any planting pattern while in 2004 the solid planting pattern had a slightly greater elongation than the skip-row pattern (Table 5). No previous research could be found that reported on fiber elongation as affected by planting pattern.

3.5 Net Returns when Comparing Planting Patterns

In 2003, the advantage in net returns for solid planting over skip-row planting was $144.96/ha (Table 6). While values for lint cotton and cotton seed were greater for solid planting, production costs were also always greater.

Table 6. Partial budget production costs for solid versus skip-row plantings in 2003 using 2012 budget values*

Variables	Solid	Skip-row	Difference (Solid-skip row)
Yield (Lint kg/ha)	1504	1347	158
Turnout (%)	36.99	35.89	1.10
Seed cotton yield (Kg/ha)	4066	3750	316
Cotton seed yield (Kg/ha)	2406	2154	252
Lint value/ha at loan	1795.78	1607.12	188.66
Cotton seed value ($/ha)	702.82	629.20	73.62
Seed costs ($/ha)	75.34	50.11	(25.23)
Technology fee ($/ha)	46.45	30.91	(15.54)
In-furrow insecticide costs	21.05	13.99	(7.06)
Banded herbicide costs ($)	25.45	16.98	(8.47)
Picking costs ($/ha)	398.56	356.69	(41.87)
Ginning costs ($/ha)	246.40	227.50	(19.15)
Advantagefor solid plantings ($/ha)			144.96

** DPL 444 BG/RR had Bollgard® and Roundup-Ready® technology with a technology fee of $262.70/bag. The loan value for solid and skip-row planting was $1.194 kg/lint while seed cotton was $292.11/ metric ton. Seed costs were $150/bag (without technology fees) based on 250,000 seed/bag while the cost of thiamethoxam seed treatment was $41.90/bag. S-metolachlor cost was $2.56/ha while flumeturon cost was $1.61/ha. Picking charge was $0.265/kg lint and ginning charge was calculated at $0.0606/kg seed cotton.*

Similar trends were seen in 2004 with net returns $245.65/ha greater for the solid planting (Table 7). In contrast, Larson et al. [13] reported that net returns for 102-cm skip-row planting were equivalent to 102-cm solid planting for low or high cotton lint prices in nonirrigated and irrigated studies. They stated that for base lint prices ranging from $0.85 to $1.38/kg, the savings in seed costs, technology fees, and harvest costs from skip rows were not enough to offset the yield reductions seen in skip-row with 102-cm row spacing.

Table 7. Partial budget production costs for solid versus skip-row plantings in 2004 using 2012 budget values*

Variables	Solid	Skip-row	Difference (solid-skip row)
Yield (Lint kg/ha)	1328	1057	271
Turnout (%)	36.00	36.00	-
Seed cotton yield (Kg/ha)	3690	2935	755
Cotton seed yield (Kg/ha)	2125	1691	434
Lint value/ha at loan	1585.63	1262.06	323.57
Cotton seed value ($/ha)	620.73	493.96	126.77
Seed costs ($/ha)	77.54	51.39	(25.95)
Technology fee ($/ha)	135.81	90.36	(45.45)
In-furrow insecticide costs ($/ha)	21.67	14.41	(7.26)
Banded herbicide costs ($/ha)	25.45	16.98	(8.47)
Picking costs ($/ha)	351.92	280.11	(71.81)
Ginning costs ($/ha)	223.61	177.86	(45.75)
Advantage for solid plantings ($/ha)			245.65

** DPL 444 BG/RR had Bollgard® and Roundup-Ready® technology with a technology fee of $262.70/bag. The loan value for solid and skip-row planting was $1.194 kg/lint while seed cotton was $292.11/ metric ton. Seed costs were $150/bag (without technology fees) based on 250,000 seed/bag while the cost of thiamethoxam seed treatment was $41.90/bag. S-metolachlor cost was $2.56/ha while flumeturon cost was $1.61/ha. Picking charge was $0.265/kg lint and ginning charge was calculated at $0.0606/kg seed cotton.*

However, in the same study, Larson et al. [13] reported that skip-row plantings produced larger net returns than solid row plantings at 25- and 76-cm row spacing under low-lint price scenario ($0.85/kg) in nonirrigated and irrigated studies. Thus, at low lint prices, savings in seed cost, technology fees, and harvest labor and machinery cost associated with skip-row plantings led to greater net returns than the solid plantings. These results support the theory of Parvin et al. [4] who stated that low prices favor skip-row plantings. To make skip-rows more profitable than solid plantings at high lint prices, a combination of increased yields from skip rows and additional cost savings (e.g., in-row chemical costs) would be needed [13].

4. CONCLUSION

Conclusions or recommendations on skip-row versus solid planting cotton favor the solid planting. In our studies, no advantage was seen with the skip-row cotton planting with plant populations from 84000 to 126000 plant/ha when compared to single row planting using 91.4 cm row spacing. Higher yields and greater net returns were seen with solid plantings and rainfall patterns failed to have an effect on the results. Differences in fiber quality between the solid and skip-row plantings were not consistently significant and therefore, along the upper Texas Gulf Coast, there seems to be no advantage to skip-row cotton plantings.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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